Modelling in Archaeology: Computer Graphic and Other Digital Pasts

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Introduction

This paper will introduce the broad context for the construction of models of archaeologically attested pasts, introducing examples from various domains in archaeological computing including network analysis, linked data and computer graphics. In each case the paper will scope the term 'model' and its influence on archaeological practice. It will then develop the idea of computer graphic models as modes for re-engaging with archaeological material and for providing new forms of space within which to build interpretations. The construction of computer models will be seen as building a history, through a series of bodily encounters mediated by the senses and by engineering and software. Questions such as the relationship between digital model experience and a former, unattainable past reality will be introduced. The paper will describe methodological concerns but focus on issues facing digital model building where so much of the material is at times contested or unknowable. In conclusion the paper will identify the place of the model in computational archaeological practice and offer thoughts on the challenges and potentials of the future.

Computational implementations of model building

Archaeology today makes extensive use of computational models. The frameworks within which they are defined and implemented now encompass a wide range of motivations, from the derivation of mathematical models for quantitative analysis to the visualisation of past environments in order to stimulate phenomenological evaluations of spatial experience. The relationship between computational practice and archaeology is a long standing one. In the UK context archaeology has been tightly bound within debates concerning information technology for a generation. This relationship has seldom been neutral. At times archaeological examples formed the esoteric, exotic case studies of choice for a ‘predatory’ computer science. At others computer science developments are influenced by an archaeology empowered by public profile and funding initiatives.

Archaeological computer modelling can be summarised as:

- Mathematical – statistical analyses
- Landscape modelling – networks, geographic information systems, geophysical data
- Data modelling – models of relations, hierarchies, objects
- Artificial intelligence and expert systems
- Textual modelling – semantics and linked data
- Computer graphic modelling – simulation and representation

Quantitative model building in archaeology has a long history, but is most clearly understood in the context of the processual movement. Given the structure of this seminar I will not go in to details of the impacts theoretical concerns have had on modelling, and I look forward to developing a greater appreciation of their impact. However it is clear that a perceived trend from processual to post-processual means for interpreting the past, and now our postmodern appreciation both of the flexibility of data and of method, has had concomitant impacts on the forms of models developed. Computational models, which at their root depend on mathematical simulations of some kind, have been dogged by a post-processual critique. Thus, landscape analyses based on visibility are seen as environmentally determinist, whilst the use of Geographic Information Systems in general have been seen as a product of the male gaze, of a desire to denude the landscape, and to impose artificial Cartesian models of space. What some have mistakenly associated with Harroway's notion of the God Trick. In statistics the model building is similarly defined as atheoretical, whilst in their application of computer graphic techniques archaeologists are accused of setting up deceptive representations that depopulate the past, and seek to sanitise experience. The postmodern critique of computation has at times been severe but in this paper I hope to identify modes of modelling that draw as much from a self-reflexive, critically aware approach to the past as lived and defined by embodied practice, as from the strings of zeros and ones that now define much of what archaeological practice is.

As a computational archaeologist perhaps the fundamental principle is the subjectivity both of method and data. To my mind all of my computational practice is archaeology – it is not a preparation for archaeology, an adjunct to it. Archaeology is not about digging or surveying or drawing but rather about coming to a new understanding of human action through material culture. Computation defines what we know about much of that material culture, and it certainly defines the later biography of the material culture as it moves from object to representation. Computation is itself tightly defined as a relationship between human and materiality and benefits from an archaeological critique. Today the digital is by far the most common mode for representing our sum knowledge of the past. Whether in a digital photograph, catalogue, spreadsheet or laser scan the physical materiality of the past is increasingly distant, whilst its digital counterpart becomes ever more beguiling and immediate. For a discipline so wedded to ideas of physical experience this could be disabling. However, I believe that computation is less problematic.

Data models define our engagement with the past as record. And such models are the product of choice, within frameworks of habit (standards) and economy. Their influence is considerable. In designing databases to express archaeological contexts for years we employed structures designed not for the intricacies of archaeological stratigraphy but rather the regularity of current bank accounts. Steadily as archaeology has grasped computation we have begun to define our own models for data, more closely allied both to our conceptions of data structures conducive to analysis but also representing the uncertainty inherent in them. It is not surprising that archaeology has produced a range of implementations of fuzzy set theory and of means to express and deal with ambiguity.

For example, in the 1990s archaeology made increasing use of artificial intelligence and in particular in the creation of expert systems. These were focussed on the automated modelling of large scale assemblages of archaeological material, and in particular on the seriation of types. More recently models of interpretative practice have been developed that seek to provide a computational framework for archaeological thinking. Work in artificial intelligence elsewhere had a significant impact on the latest developments in web technologies, and here again archaeology has made significant advances. Our own work at Southampton has focussed on semantic web applications for modelling archaeological data.

The semantic web envisages a structure for the web enabling reasoning via exacting definitions both of data and the connections between it. The linked data community has pursued a policy of simplification, focussed on a bottom up model building process. Here the focus has been on structuring archaeological data according to a series of unique identifiers, thus enabling shared understanding. Attempts to model reasoning through defined chains of inference have been replaced by a pragmatic interest in connectivity. Thus, in our work in Roman ceramic distributions across the Mediterranean we have developed a system for modelling the shared aspects of apparently divergent datasets. We explore records for ceramics defined in different languages, according to varying data structures and link them according to shared conceptual models. For example, we identify shared understandings of the form of the ceramic, and aspects of its archaeological biography such as excavation context. Such an approach is dependent on the ability to uniquely identify concepts such as place, period and type which in turn requires consensus. However, since linked data enables parallel data models to develop it is possible for archaeologists working in different contexts to continue to apply their own models of archaeological data whilst at the same time enabling cross-cutting interpretations in the future. To an extent the success of this will rely on consistent definitions of provenance.

Computer Graphic Models in Archaeology

In the remainder of today’s talk I will discuss the particular form of model building with which I am most closely involved. Computer graphic modelling forms an increasing part of archaeological practice, implicated in modes of recording of objects and spaces, the interpretation of types, the management of three-dimensional information, creation of artificial experiences of place for interpretation, and the representation of archaeological ideas to a broader public.

Computer graphics loosely defined are digital three-dimensional representations of objects constructed from a network of points. These points are generally connected together to form a mesh of triangular facets interpreted by the computer as physical objects. In turn these facets are made to behave in ways similar to the real environment, taking on properties such as colour, reflectivity, transparency and influencing their surrounding digital environment by bouncing light, casting shadows and obscuring other objects.

These multi-coloured, complex meshes exist with a set of Cartesian co-ordinate systems generally viewed either in conventional models such as the orthographic and isometric, through virtual cameras, or through attempts to mimic human vision. Drawing conventions partition three-dimensional objects into two-dimensional abstractions in order to enable delivery through a computer screen or printed. Here the model of space is tailored to Cartesian measurement and for the comparison of proportions. This is the window onto the modelled past through which the computational archaeologist looks. My postgraduate students spend many months building a familiarity with archaeological sites and objects that is profound, yet wholly artificial. They are encouraged to engage with the materiality of the past at the same time in order to build connections between the models and their reality. And in this way the models on the screen build up a tangible life history that is personal but also crucially can be shared. It is an externalised vision. However, it is unclear the extent to which the computer graphic is an instantiation of an internal model or if in fact it is the process that defines both the model and the understanding of the physical object or place. In any case the structure of the interface has a considerable impact on the digital archaeologies that emerge.

Virtual cameras by comparison mimic the optic properties of still or film cameras in order to convey three-dimensional digital geometry in a form that stimulates the perceptual responses associated with photographs and movies. The motivation behind this is complex. Archaeology is a discipline versant in alternative modes of visual representation. The physical practice of archaeology both in the field and the laboratory is tied to the production of visual metaphors. The excavated section through the ground is rendered on cleaned, two-dimensional orthogonal axes. Thus, the computer modelling package similarly divides up the virtual world into a series of two-dimensional representations. By comparison, the overall view of an excavated trench is constructed through a site photographs, constructing conventional forms such as scales and parallel edges. Thus, the virtual camera attempts to draw on these familiar forms of archaeological spatiality in order better to convey the form of material remains. In addition, the virtual camera can draw upon the emotional responses associated with particular photographic forms and, in the case of moving cameras, cinematography. The virtual camera constructs a view of the geometric data specifically to develop emotional, perceptually distinct engagements with the past, mediated not by glass and earth but pixels and geometry.

The final form of visual engagement comes through attempts to mimic human vision. Here rather than adding artefacts to visual experience – lens flair, chromatic aberration, depth of field and so on – the visual representation is tailored by field of view, perspective and depth perception, and lighting accommodation. The computer model is thus seen not as a constructed visual artefact but rather as a new place within which to undertake archaeology. Spaces defined by lists of x, y and z co-ordinates are transformed thorough practice into places with their own biography.

Case Study 1 – Model building for formal analysis

In this first case of archaeological computer graphic modelling I will demonstrate the application of geometric models for formal analysis of space. Archaeology has appropriated a number of analytical tools from architecture. These have a number of aims:

1. Structural analysis
2. Formal comparison between multiple archaeological environments
3. Quantification of perceptual stimuli

Structural models are those which represent physical interactions in a realistic way. In architectural and engineering terms finite element analysis models the physical tolerances between interacting forms – whether a given architectural form will stand up, will support a given weight, will react to environmental impacts, and so on. Thus at Southampton we are just beginning a project that will model archaeological environments and the impact of flood upon them, and also explore past responses to such climatic events. We have also used structural analysis as part of the construction of hypothetical models. As so much of the archaeological record is fragmentary the process of extrapolation from plan to volume to visualisation frequently requires clarification. One might well envisage a site such as Woodhenge in southern England roofed, but do the surviving remains support such a hypothesis? Structural modelling therefore offers one tool for critiquing and iterating models.

These spatial models interpreted from archaeological data are frequently used alongside ethnographic data in order to derive hypotheses about past social interactions. This process of ethnographic analogy has in the past used tools for simplifying spatial structure. Most prominent of these are Access Analysis and the work of the space syntax group. Frequently structuralist in orientation, these model building exercises are often applied in architectural contexts. For example, formal analyses of spatial interconnectivity have been seen at Ostia and Pompeii in Italy, and at a wealth of medieval sites in the UK. Such formal models distil the complexities of space into graphs, commonly representing potential or actual human physical movements. Thus Access Analysis, provides an assessment of relative special distance, expressed as the number of ‘rooms’ traversed in travelling between one space and another. This model is then considered in terms of social interactions with the space seen both as the mode through which social relations are formed and reinforced, and expressions of social relations, sedimented in brick and stone and earth.

Our own work in this field has concentrated on visible connections between spaces, with these connections being seen as of significant to those both building and inhabiting the spaces. We have developed a technique known as Texture Viewsheds which allows a fully three-dimensional geometric model of a space to be analysed such that qualitative appreciations of it – concepts such as liminality, enclosure, encounter and circulation – may be formally expressed. In work at the House of the Birds, a Roman town house at the site of Italica near to modern Seville in southern Spain, we have explored movement around the building and its impact on the visual appreciation of different regions. Such a quantitative approach is frequently used alongside more qualitative appraisals of space, such as that undertaken in houses at Pompeii using game engines, and that I will describe in more detail later on.

Another common focus for formal analyses has been in terms of lighting. Thus, computer graphic models of light transport within a scene are now sufficiently accurate – measured both in terms of measured levels of luminant and illuminate energy and of visual fidelity – that architects can design buildings knowing exactly how they will appear under given conditions. In turn they can assess the forms of tasks that can be habitually undertaken in these conditions. Such functional models of potential behaviour have been applied in a number of archaeological cases to assess the likely activities associated with given spaces. Such studies have demonstrated interesting results. For example, the classic study of Thule whalebone architecture showed that the artificial illumination available in these structures meant that most activities must have taken place outdoors or seasonally. Konstantinos Papadopoulos at Southampton has similarly studied a Neolithic pottery workshop in Greece in order to assess likely activity areas. However, whilst interesting such studies inevitably pose problems. Firstly, the metrics against which the models are tested derive from contemporary studies of activity, frequently in an office environment. Secondly, the input data must be perfect. One must have a very good understanding of the spectral properties of the luminaires for example, and also of the environment, and its form. Thirdly, whilst particular levels and types of lighting may not be conducive to optimum performance in a given task – for example sewing or knapping – this need not preclude it. Finally, the social and cultural influences on activity areas are ignored. Accurate lighting models tell us what was impossible and possible but a very limited amount in between, not least in terms of intentionality.

Visual connectivity defined by Texture Viewsheds or related methods such as Visibility Graph Analysis (VGA) and GIS-based Cumulative and Total Viewshed analyses is not the only form of perception that is subject to formal analysis. Formal acoustic modelling is also gaining popularity within archaeology. Here arguments focus largely on the same questions of intentionality. For example, a Neolithic chamber tomb may well have specific acoustic implications but are these a deliberate consequence of the structure of the tomb? Furthermore, were these acoustic consequences of relevance to those using the space in the Neolithic? For example, did they perhaps define a multi-sensory experience based on drumming, artificial illumination with smoke and smells, the cool and texture of the stones and ritual consumption of food?

The problems with all such formal methods are clear. First, as has been identified, we are dealing with a fragmentary record and one that is temporally and culturally distant. Whilst architecture can evaluate the social impact of a given set of spaces on a proposed building, basing its findings on a detailed understanding of contemporary behaviour, archaeology must not only work from a partial model of the space but it then seeks to develop an understanding of social interactions stimulated by, and stimulating spatial form. Secondly, formal analyses of space are simplifications of complex bodily experiences in space which are clearly socially and culturally constructed. Although spatial models of human behaviour can provide a good fit to practice in a modern context – the agent and VGA based study of the Tate gallery being an exemplar – it does not follow that this can translate to the archaeological past. Furthermore, formal analyses require a separation of the senses. At times we must separate out senses in order that the practicalities of their artificial stimulation can be defined – acoustic simulations require headphones or speakers, visual simulations head mounted displays, monitors or projectors – but we also divide out those perceptions on practical, interpretative grounds. One might therefore perform a visibility analysis and an acoustic analysis of the same location, and then attempt to integrate their results. What is unclear is the extent to which in reality we are able to recombine such formally distinct perceptual analyses in order to return to a subjective, bodily, multi-sensory experience. Interestingly the fact that such a distinction between sensory apparatus may well be wholly artificial has been appreciated by computer scientists interested in the creation of digital experience. Their quest for wholly realistic, wholly artifical stimulation of the senses – sometimes termed multi-sensory rendering – is based on a holistic, at times synaesthetic understanding of perception. It is to these efforts to create experience that I shall now turn.

Case study 2 – Model building for experience of past lifeways

In my second case study I would like to address the nature of the engagement with the past that derives from computer graphic modelling. In particular I would like to explore the nature of bodily experience in simulated spaces; how real can a virtual encounter be and how can we equate this to experience in the past?

The site of Herculaneum in Italy was buried by the same eruption of Mount Vesuvius that buried nearby Pompeii in AD79. Working as a collaborative team including colleagues from the Herculaneum Conservation Project and the University of Warwick we are currently exploring the possibilities for computational methods to record and represent aspects of Herculaneum as we believe it was just prior to the eruption and to the subsequent drowning of the town in a wave of superheated mud twenty metres thick. In addition to laser scanning and polynomial texture mapping of various materials we are particularly interested in a Roman statue thought to date from the first century BC that was found buried in the Basilica Noniana near to Herculaneum's still buried forum. The statue, interpreted by some as of the *Sciarra* wounded Amazon type, has rich traces of its original pigment and was recovered from a building about which much is known.

We are conducting a programme of intricate recording and digital reconstitution of the damaged surface and its pigments in order to place the statue back in its hypothesised original context. Some evidence suggests that statues were moved quite commonly in the Roman world. They were also adorned with flowers and draped in fabric, and even supplemented by metal and precious artefacts. This, and the fact that the pigment was modified by the eruption and only now survives in a fragmentary form, means that physical reconstruction of the statue is impossible. Whilst an art historian may faithfully reconstruct Roman pigment – as with the exemplary Gods in Colour exhibition – this process can be repeated only a few times. Cost and time prohibit the variability inherent in archaeological interpretation. So we have chosen computer modelling to reconstitute the statue. This is no simple feat, as accurate surface simulation (as opposed to the creation of visually appealing digital artworks) is extremely computationally intensive and requires a great deal of surface data.

It is our belief that the fidelity of representation will mean that we will look, with our eyes, upon a statue as it was last seen two thousand years ago. We will look on it with the light of the Bay of Naples, surrounded by the vivid paintings of the Basilica or dappled by light in a nearby garden. We are interested not only in how the statue would appear were the Basilica Noniana standing now and the statue was as originally created, but more than that we are seeking to follow a trail of experience to Roman encounters with the statue. We are seeking to tease out Roman questions of style, intentional position and juxtaposition. And for this we must accept a relationship between the modelled space and some imagined Roman past, that whilst imagined has a real sense of place in time. However, must we therefore accept the past as having existed in a way objectively verifiable; in a sense if the model is good enough can we return to the truth of the past, accepting Baudrillard's concept of the simulacrum? Will our interpretations ever escape the context of the computer model?

Case study 3 – Model as thinking space

In my third case study I shall introduce the site of Catalhoyuk in Turkey. This Neolithic site was inhabited 9000 years ago within the broad period when agriculture was first developed. Our work here is primarily about providing new digital spaces to think inside. Such an approach has had prominent critiques from within archaeological theory, most notably Thomas (2004) who dismissed attempts to add a human dimension to computational practice. Similarly Lock (2003) has warned against equating digital and real experience, or at least in undertaking analyses of experience in these two realms using similar methods and theoretical frameworks.

Such criticisms stem from an understanding of the digital model as standing in for a real past. As discussed above this introduces a problematic if one sees the past as objectively unknowable. However, one might rather see the model as simply a mode of visual stimulation, as a conflation of archaeological data designed to stimulate thought. Elsewhere I have written about the relationship between the photorealist painting movement and the forms of photorealistic graphics we produce:

> "Rather than implying a physical duplication of a past reality through computation, or artificially simulating a world as it is imagined to have

> appeared, instead the archaeologist takes physically accurate vignettes and constructs from them an archaeological narrative, through rich interpretation." (Earl 2009)

I believe that it is vital that the inputs to such interpretive collage are physically correct – in other words, one must follow through the processes outlined above to ensure that the model generates perceptual responses as close to the real world as possible. However, having produced these views of the past digital archaeology then remixes them. At Catalhoyuk and elsewhere we are building spaces that have very considerable perceptual realism but we do not take them for reality. Rather they provide an ever changing set of places for visualising the information available to us. In particular at Catalhoyuk they are enabling us to take the fragmentary archive of the earlier 1960s excavation of this fragmentary site and combine it with the modern excavation results in order to produce sensory experiences. What remains for us to understand is the nature between these digital experiences and the development of new interpretations.

In part because of this uncertainty we are also working on a new project that will produce a multi-sensory blend of the physical and digital in archaeological fieldwork. Habitual field process has a rhythm that to a degree dictates the archaeology that results and we are not sure how the incorporation of the digital will impact this. However, we will use this to inform an understanding of purely digital experiences in the future.

Case study 4 – Model as representational device

In my final case study I will describe the computer graphic model as explicitly representative device. On the Portus Project, funded by the UK Arts and Humanities Research Council, we have made extensive use of computer graphics. Firstly, to build visual interpretations as the excavations unfolded; secondly, to analyse structural forms on site, and finally to present the variety of our findings to a broad public. In Autumn of 2009 this latter aspect took on a fundamental role as the site was at the centre of media coverage that spread across the world and representational media. Of the two iconic images from that time one – a hypothesised amphitheatre – was wholly digital. Not only was it digital but it was constructed in a matter of minutes as a model for interpretation, as an ephemeral thing, a part of archaeological process. It has become the defining view of the architecture of the site, alongside a partially buried statue that defines the site's mystery and wealth.

Portus was the port of Imperial Rome. In the first century the Emperor's Claudius and Nero created an enormous artificial harbour large enough to hold at least two hundred Roman ships. In the second century the harbour was extended to include a huge hexagonal basin that remains visible from space on the coast to the west of Rome. Portus thus poses problems of scale for those trying day by day to interpret it, and for those unacquainted with the site it is often impossible to visualise. For this reason we have produced a wide range of models of the different components of the site. Some of these are structured along conventional narratives as stills or animations, whilst others such as models in Google Earth, Second Life and Unity3D enable interaction. Critiques of these models have focussed on the same argument that has been levelled at archaeological computer graphic modelling for twenty years: since so much of the past is fragmentary it is our responsibility to illustrate the past in such a way that our uncertainties are clear. We must demonstrate the authenticity of the varying portions of our representations. Many technological and stylistic approaches have been proposed in this context, including varying uses of transparency, digitally signposting particular elements and degrading the visual fidelity of the areas that are considered less certain.

My reaction has been that such attempts whilst useful in a museological context to represent archaeological process are not necessary components of digital representations. As discussed above the beauty of the photorealist painting is the mixture of construction and stimulation. It is a known falsehood wrapped up as truth. I believe that the computer graphic modeller may choose to represent the past in a way that has no indication of uncertainties and arguments, providing the context makes clear that these exist. It is for this reason that computer graphic models so seldom depict humans. It is not to sanitise the past but rather to remove the elements that more than anything show digital models for the constructions that they are. One cannot pick apart the interpretative processes, the inference chains, that lead to specific representations other than at a largely superficial level. Since digital archaeology is archaeology it is complex, messy, emotional, subjective. The process deserves critique, of the form exemplified by our own Stephanie Moser, but does not need to be restrained.

Conclusions

Archaeology continues to battle with its position in terms of model building and critique. CP Snow's artificial distinction still has resonance in the structures of archaeology where archaeological science, archaeometry, archaeology and anthropology dance slowly around and in and out of one another. The model as testable, absolute metric for past behaviour to is increasingly restricted to formal models of isotopes, osteological traits or ceramic inclusions. But beyond these archaeology lacks certainty. It is at once a discipline familiar with and embracing of diversity and community. Archaeology in each of the examples I have introduced is an intensely political activity. The models therefore must ebb and flow with cultural sensitivities and be prepared to be shattered over and over again.